Performance of Sound Absorption and Noise Reduction for Dislocation Honeycomb Sandwich Panel With Built-in Coating

Jian Wang

College of Public Management, China University of Mining and Technology, Xuzhou, China.

Jianwei Cheng and Wanting Song

College of Safety Engineering, China University of Mining and Technology, Xuzhou, China.
E-mail: Cheng.jianwei@cumt.edu.cn

Yidan Zhu

Institute of Urban Safety and Environmental Science, Beijing Academy of Science and Technology, Beijing, China

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The effects of diatom mud coating on characteristic impedance is studied by using the double-thickness method. The parallel relationships among the concave arc column filled with diatom mud, honeycomb cells, the overall core layer, and micro-perforation are considered in using the acousto-electric analogy method. In the case of a series relationship of plates, the sound absorption coefficient of the honeycomb structure of the micro-perforated plate is calculated. The effects of diatom mud coating and dislocation arrangement on the sound absorption coefficient of sandwich panels are numerically simulated by COMSOL. To further verify the reliability of the sound absorption theoretical model, test specimens are made and the effects of dislocation arrangement and diatom mud coating on sound absorption performance are tested by using impedance tube equipment. The effect of dislocation arrangement and diatom mud coating on the sound absorption performance of low-frequency noise of sandwich panels is analysed from the parameters of sound absorption coefficient, resonance frequency, acoustic impedance, and fitting results.

1. INTRODUCTION

In engineering applications, passive noise reduction methods are commonly used for reducing the noise in low-frequency band. To improve passive noise reduction performance, two approaches are generally considered: sound insulation and absorption. Based on the analysis of relationships between sound insulation, frequency and quality, the elimination of noise in medium /low frequency bands usually requires several times of mass quality to achieve good reduction effects. Although the low-frequency sound absorption performance of the micro-perforated plate is good, the frequency of the absorption peak is roughly inversely proportional to the height of the micro-perforated plate cavity. Therefore, it is difficult to achieve low-frequency sound attenuation when the thickness of the structure is highly controlled. Therefore, if the thickness and quality of noise reduction components of mechanical equipment are both required in engineering applications, it is a big challenge for engineers.[1–8]

With the development of the honeycomb sandwich structure of micro-perforated panels, some researchers have combined the built-in sound damping structure with the honeycomb sandwich. Structural vibration and resonant frequency changes have varying degrees of influence.

Han et al. studied the effect of porous fiber sound-absorbing material filling the rectangular honeycomb structure on the sound absorption performance and the combined the standing wave phenomenon generated in the propagation of obliquely incident sound waves with the three-dimensional theoretical model. In the case of oblique incidence, the porous material fills the honeycomb structure to improve the sound absorption performance of a single porous material.[9]

Koch et al. studied the damping effect of particulate materials by filling particles in a high-stiffness honeycomb structure. The cavity structure of the honeycomb can achieve a specific distribution of particles in space, thereby improving the vibration and noise reduction performance of the structure. The bottom case was used as the test carrier. The influence of the mass, distribution, and type of particulate matter on the vibration characteristics of the structure was studied by the laser scanning vibration measurement method.[10]

Tang et al. proposed a new type of micro-perforated honeycomb corrugated sandwich panel composite structure. Based on the composite sandwich panel, micro-perforations of different diameters were introduced into the micro-perforated panel and the corrugated sandwich. A good low frequency was obtained. On this basis,[11] the performance of the structure at high temperature is studied. The results show that it has a wider absorption band and better low frequency performance at a high temperature.[12]

Li et al. proposed a lightweight multi-layer acoustic structure composed of honeycomb cores and films with the same number of layers, which enhanced the noise reduction performance in the mid-low frequency range. Influence when the thickness of the structure is 4.2 mm and the unit mass is 0.29 kg/m^2, the transmission loss can reach 17 dB.[13]

In previous studies, most of the research was on either honeycombs with different shapes or the addition of damping materials, while the arrangement of the honeycomb core layer and influence of sound insulation and absorption properties of sandwich panels was rarely studied.

Diatom mud is a nano-scale porous material with a porosity of more than 85%. According to its microstructure, the pores of diatom mud intersect with each other and connect with the outside, which is a typical structural feature of porous materials having good acoustic performances. Studies have shown that diatom mud has a good sound absorption effect after being prepared with other materials to form composite material, but there are few studies on diatom mud coatings' effects on layers of the acoustic performance of composite structures.[14–17]

To summarize, most of the research focuses on the honeycomb core layer with different shapes and damping, while the arrangement of the multilayer honeycomb and the sound-absorbing coating and honeycomb structure. There are few combined studies. The micro-perforated honeycomb sandwich panel has poor sound absorption frequency at medium and low frequencies. In this paper, a dislocation honeycomb structure with built-in diatom mud coating is designed, which can improve the acoustic performance of the sandwich structure at medium and low frequency bands. A study of its acoustic performance is carried out.

2. HONEYCOMB WICK SOUND BSORPTION THEORETICAL MODEL

According to references,[18, 19] for pipes with a cross-sectional area less than 1 cm^2, the acoustic resistance per unit length can be written as:

$$R_a = \frac{\rho_0 c_0 D}{2S^2} k_0 \left[d_\mu + (\gamma - 1) d_\kappa \right]. \quad (1)$$

In the formula: D—Arc column section perimeter; S–Sectional area; d_μ—The thickness of the viscous boundary layer on the inner wall of the cavity; d_κ—Thermal boundary layer thickness of cavity inner wall.

The acoustic reactance of a cavity of length h can be expressed as:[20]

$$X_a = -\frac{\rho_0 c_0}{S k_0 h}. \quad (2)$$

When the depth of the circular lumen is h, the acoustic impedance can be expressed as:

$$Z_c(h) = \frac{Dh}{2S^2} k_0 \left[d_\mu + (\gamma - 1) d_\kappa \right] - \frac{j}{S k_0 h}. \quad (3)$$

The cavity of the inner concave arc column was filled with diatom mud porous sound-absorbing material. It can be regarded as a diatom mud plate structure with a small cross-sectional area and a certain thickness. The surface acoustic impedance can be determined by experimental methods. Two test methods, the double-chamber method[21] and the double-thickness method,[22] are usually used. The principle of the double-thickness method is as follows: the specimens with the thickness of l and $2l$ are selected, respectively. The corresponding surface impedances Z_{s1} and Z_{s2} are tested by the standing wave tube. It can be concluded that the characteristic impedance Z_s of the concave arc column filled with diatom mud is:

$$Z_s = \sqrt{Z_{s1}(2Z_{s2} - Z_{s1})}. \quad (4)$$

The relative acoustic impedance of the micro-perforated plate is calculated using the sound absorption theory of the micro-perforated plate proposed by Ma,[23] the acoustic impedance Zmpp of the microplate can be expressed as:

$$Z_{mpp} = r + j\omega m. \quad (5)$$

In the formula: r—sound resistance; m—sound quality.

$$r = \frac{32\mu}{pc} \frac{t}{d^2} \left[\sqrt{1 + \frac{x^2}{32}} + \frac{\sqrt{2}x}{8} \frac{d}{t} \right]; \quad (6)$$

$$m = \frac{t}{pc} \left(1 + \frac{1}{\sqrt{3^2 + \frac{x^2}{2}}} + 0.85 \frac{d}{t} \right). \quad (7)$$

In the formula: $x = d\sqrt{\frac{f}{10}}$; d—Micropore diameter; t—plate thickness; μ—air viscosity; p—Perforation rate; c—speed of sound in air.

According to the acoustic-electrical analogy method, when studying the sound absorption coefficient of the composite structure, the circular cells in the honeycomb core layer can be connected in parallel with the concave arc column filled with diatom mud and then connected with the micro-perforated plate in series to obtain the composite structure. The characteristic impedance is expressed as:

$$Z = Z_{mpp} + \left(\frac{\phi_c}{Z_c} + \frac{\phi_s}{Z_s}\right)^{-1}. \quad (8)$$

In the formula: ϕ_c—The ratio of circular cells to the cross-sectional area of periodic structures; ϕ_s—The ratio of the inner concave arc column to the cross-sectional area of the periodic structure, $\phi_c + \phi_s = 1$.

The overall sound absorption coefficient of the composite structure can be expressed as:

$$\alpha = \frac{4\mathrm{Real}(Z)}{(1 + \mathrm{Real}(Z))^2 + (\mathrm{Imag}(Z))^2}. \quad (9)$$

3. SOUND ABSORPTION COEFFICIENT SIMULATION

To study the effect of dislocation arrangement and diatom mud coating on the sound absorption performance of the micro-perforated honeycomb sandwich panel structure, COMSOL was used to study the changes of sound absorption coefficient. The selected material parameters were as follows: the honeycomb side length was 2.75 mm, the honeycomb single layer thickness was 2 mm, and the honeycomb core wall thickness was 0.3 mm, the perforation diameter of the micro-perforated plate was 0.5 mm, and the thickness of the aluminum plate was 1 mm. The density of diatom mud coating was 480 kg/m^3 and the thickness was 0.2 mm (0.1 mm each side). Since many literatures have done thorough research on the influencing factors of micropore diameter, perforation rate, panel thickness, etc., this paper only discusses the effects of dislocation arrangement and diatom mud coating on the sound absorption performance of sandwich panels.

The dislocation honeycomb structure of the micro-perforated plate with different dislocation layers is shown in

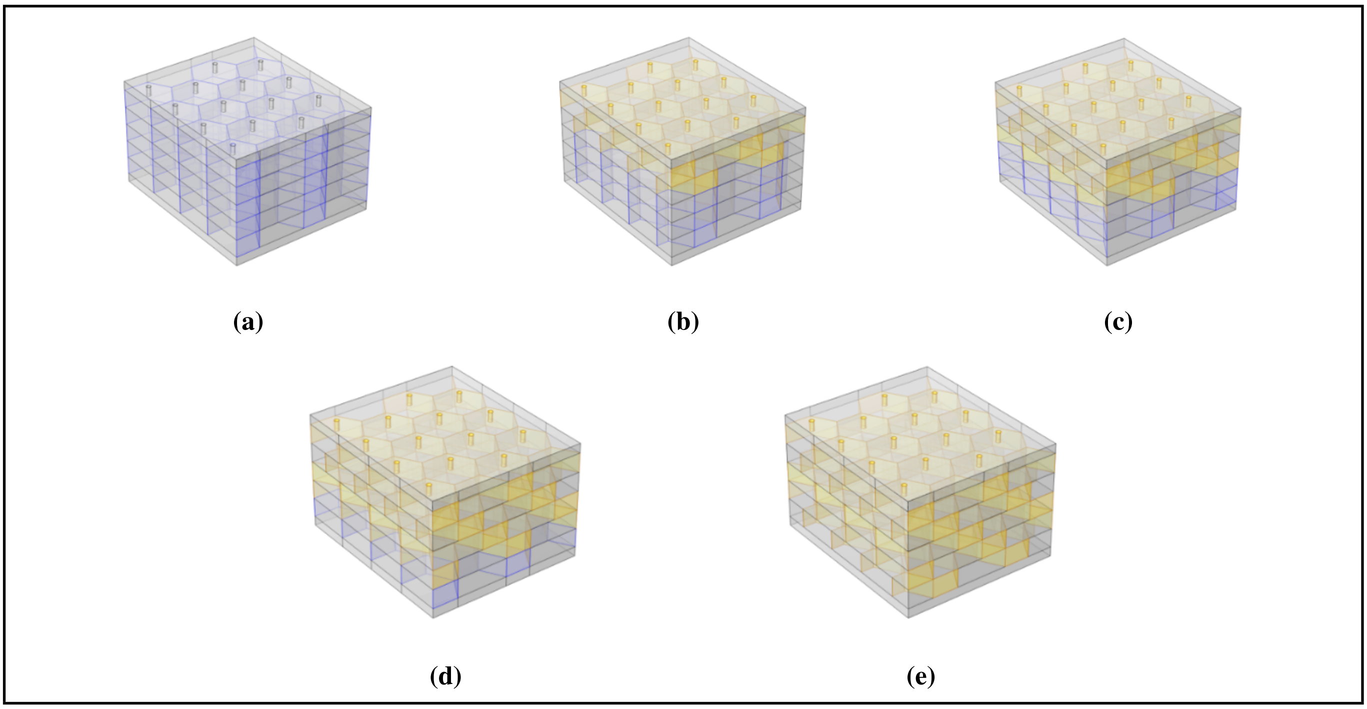

Figure 1. Honeycomb core layers with different dislocation layers: (a) zero layer; (b) two layers; (c) three layers; (d) four layers; (e) five layers.

Figure 1. The blue part is the number of aligned honeycomb layers, and the yellow part is the number of dislocation honeycomb layers.

The effect of the number of dislocation layers on the sound absorption coefficient is shown in Figure 2. With the increase of the number of dislocation layers, the peak value of the sound absorption coefficient gradually increased and was over 0.9. The resonance frequency moved to the low frequency direction, and the peak shifting to the left shows that the sound absorption performance of the composite structure was improved in the middle and low frequency bands, but the sound absorption performance of the dislocation structure was slightly lower than that of the aligned structure in the middle and high frequency bands. The dislocation structure had little effect on the bandwidth of the effective sound absorption band. The full five-layer dislocation structure moved the resonance frequency of the sandwich panel structure to the left by about 300 Hz, and the peak sound absorption coefficient increased by about 0.05. The dislocation of the second and fifth layers had a greater impact on the structure, and the dislocation of the third and fourth layers to the low frequency direction was small. To sum up, the dislocation arrangement can improve the sound absorption performance of the structure.

When studying the effect of diatom mud coating on the sound absorption coefficient of the honeycomb sandwich structure of the micro-perforated panel, the structural parameters should be kept unchanged. Only the number of coating layers should be changed. The sound absorption coefficient of the sandwich panel structure has almost no effects, so the simulated sound absorption results can reflect the influence of the diatom mud coating. The dislocation honeycomb structure of the micro-perforated plate with different dislocation layers is shown in Figure 3. The number of uncoated honeycomb layers, and the yellow part is the number of coated honeycomb layers.

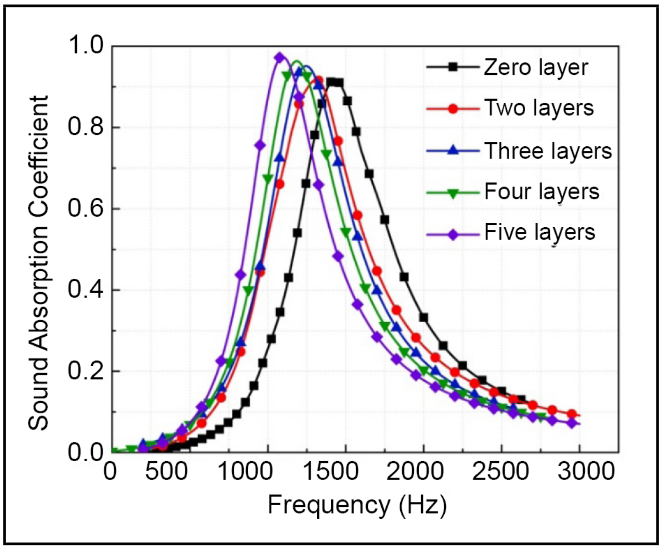

Figure 2. Simulation results of the effect of the number of dislocation layers on the sound absorption coefficient.

The effect of diatom mud coating on the sound absorption coefficient is shown in Figure 4. With the increase of the number of coating layers, the peak value of the sound absorption coefficient remained unchanged or even decreased, but the peak value of the sound absorption coefficient remained at 0.85–0.9 This was because the diatom mud coating has a sound absorption effect. However, according to the theoretical derivations, the diatom mud coating has a certain influence on the acoustic impedance and acoustic impedance. Thus, the calculated sound absorption coefficient changed little. The diatom mud coating moved the resonance frequency of the sandwich panel structure to the low frequency direction, and the peak shifting to the left improved the sound absorption performance of the composite structure in the middle and low frequency bands. The diatom mud coating broadened the effec-

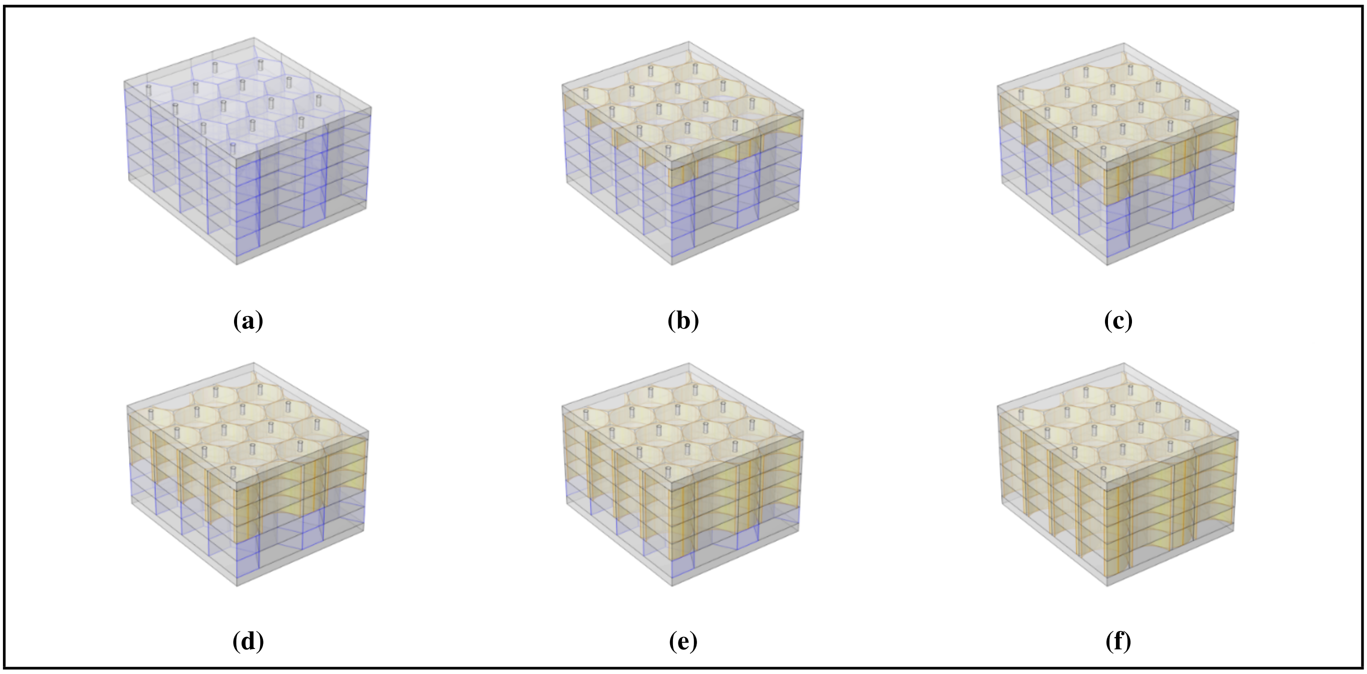

Figure 3. Honeycomb core layers with different diatom mud coating layers: (a) zero layer; (b) one layer; (c) two layers; (d) three layers; (e) four layers; (f) five layers.

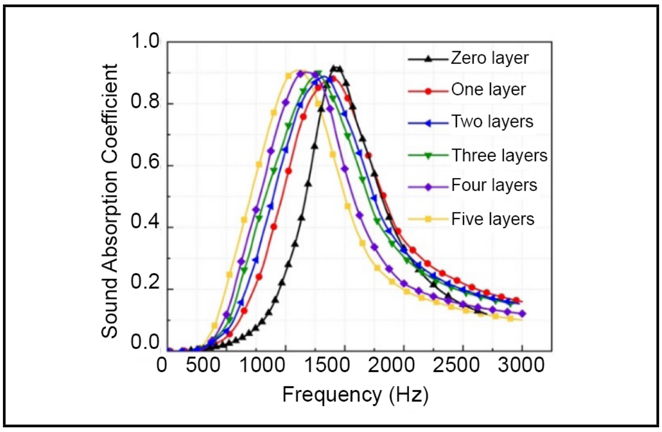

Figure 4. Simulation results of the effect of the number of coating layers on the sound absorption coefficient.

tive sound absorption frequency band of the sandwich panel structure and increased the effective sound absorption range by about 100 Hz. It also improved the sound absorption performance of the sandwich panel structure. The full five-layer coating structure moved the resonance frequency of the sandwich panel structure to the left by about 300 Hz. The coating accelerated the change trend of the sound absorption coefficient of the sandwich panel structure. The coating structure reached the effective sound absorption coefficient of 0.4 at 600 Hz comparing to that of no-coating structure at 1200 Hz. In summary, the diatom mud coating can improve the mid-low frequency sound absorption performance of the sandwich panel.

4. EXPERIMENT

The test device, BK4206 impedance tube was used. The inner tube diameter was 100mm, which can be used in the frequency range of 63∼1600 Hz. The device is shown in Figure 5.

The main materials in the test process were: aluminum plate, micro-perforated aluminum plate, NOMEX honeycomb, diatom mud, No. 801 super glue. The dimensions of the material were selected as follows:

In this paper, an aluminum plate with a thickness of 1 mm was selected. The perforation rate of the micro-perforated plate was 0.7%, and the diameter of the micro-pore was 0.5 mm. The height of the honeycomb core was 10 mm, the density was 48 kg/m^3, the thickness was 2 mm honeycomb core layer; the binder was No. 801 super glue. In this paper, SEM (Scanning Electron Microscopy) was used to characterize the micro-scale pore structure of diatom mud. Figure 6 shows the micro-scale pore structure of diatom mud observed by SEM. The diatom mud used in the test is composed of irregular-shaped particles with particle sizes ranging from 1 to 10 μm and there are layered stacks at the edges of the particles. The particles were randomly stacked with each other, forming many micron-scale pore structures. Due to the randomness and uniform distribution of the particles, the pore structures were connected to each other along the edges of the particles to form channels, which were the connected open pore structures required in this experiment. At the same time, there are many open-pore structures on the surface of diatom mud that are connected to the outside. The pores were irregular in shape and connected with the internal channels, which together constitute the porous sound-absorbing material required for the test.

Due to the limitation of the test device, the diameter of the entire sound-absorbing structure was 99 mm, and the edge of the structure is sealed with Teflon tape, which not only ensures that the sample was tightly fitted in the impedance tube, and prevents the sound from leaking from the surrounding cracks or gaps, At the same time, it can reduce the influence of the inconsistency of the honeycomb edge, and can also play the role of protecting the test device.

The upper panel of the test piece was made of aluminum plate with perforation rate of 0.7%, perforation diameter of 0.5 mm and thickness of 1 mm, and the lower panel was an

Figure 5. Impedance tube test device.

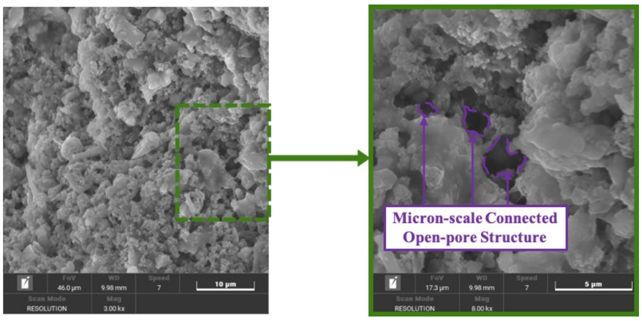

Figure 6. SEM image of diatom mud.

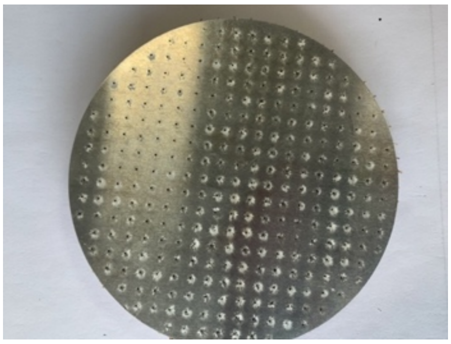

Figure 7. Microperforated plate for experiment.

aluminum plate with a thickness of 1 mm without perforation. The total thickness of the composite structure was 12 mm and the diameter was 99 mm. The above structural parameters remained unchanged during the test.

The micro-perforated plate was processed by laser drilling, and the actual picture is shown in Figure 7. The core layer was a NOMEX honeycomb, which was cut into a circle with a diameter of 99 mm, as shown in Figure 8. The lower panel used an unpunched aluminum plate with the same parameters as the micro-perforated plate, as shown in Figure 9. No. 801 super glue was used to bond between the panel and the honeycomb and between the honeycomb and the honeycomb.

In the traditional micro-perforated plate-honeycomb structure, the honeycomb core was straight, as shown in Fig. 10(a), which can be regarded as several layers of honeycombs with smaller thickness stacked together, as shown in Fig. 10(b).

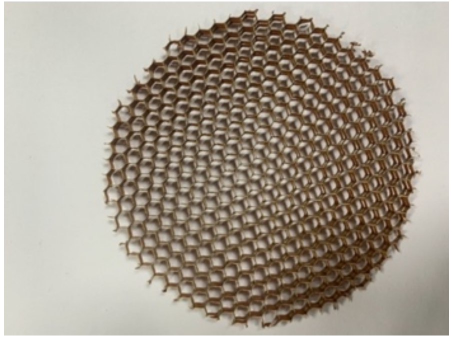

Figure 8. Honeycomb sandwich for experiment.

Figure 9. Aluminum plate for experiment.

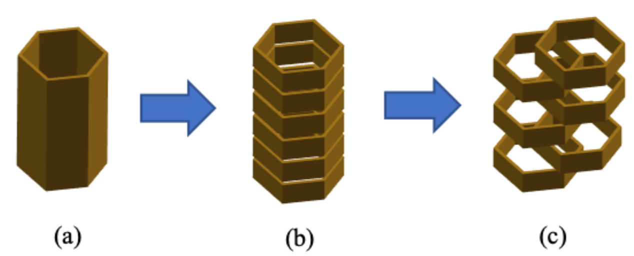

Figure 10. Traditional aligned honeycomb and misaligned stacked honeycomb.

The dislocation stacked honeycomb studied in this paper was placed in the honeycomb in Fig. 10(b) in an unaligned but regular way, as shown in Fig. 10(c).

To show the dislocation arrangement structure more intuitively, a small number of honeycomb units are used as an example to draw the stacking method between layers. As shown in Figure 11(c), since the shape of the hexagonal honeycomb was regular and symmetrical, every three adjacent honeycombs arranged in a triangle were stacked in such a way that the area of the adjacent upper and lower honeycombs was divided into three equal parts. Displacement stacking according to the same rule, to ensure as few variables as possible, so that the test results are as accurate as possible.

The process of preparing the honeycomb core covered with diatom mud coating was as follows: soak the cut honeycomb in diatom mud, and then clip the honeycomb out after complete immersion. When clipping out, it should pay attention to the stress points on the upper and lower sides of the honeycomb, and it do not damage the honeycomb wall. After the coating

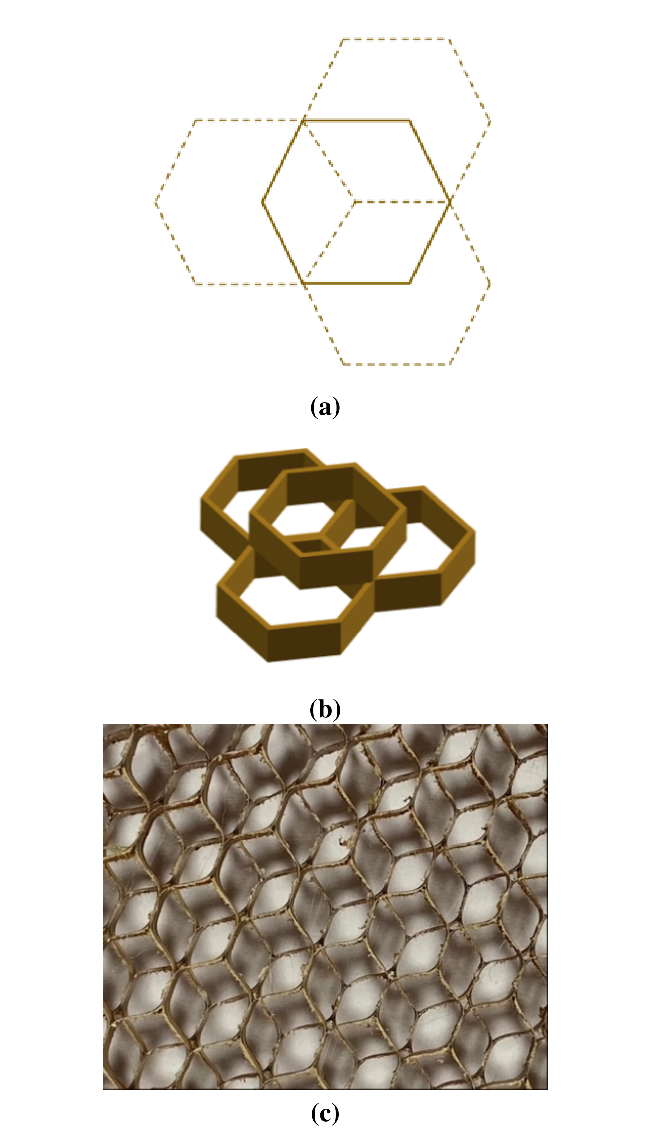

Figure 11. Schematic diagram of dislocation arrangement: (a) plan view; (b) three-dimensional view; (c) physical view.

Table 1. Changes of parameters related to changing honeycomb arrangement.

Specimen number	Dislocation stacking layers/layer	Number of coating layers/layer	Change of mass /g	Change of thickness /mm
1	0	0	0	0
2	2	0	0	0
3	3	0	0	0
4	4	0	0	0
5	5	0	0	0

Table 2. Changes of parameters related to changing the number of coating layers.

Specimen number	Dislocation stacking layers/layer	Number of coating layers/layer	Change of mass /g	Change of thickness /mm
6	0	0	0	0
7	0	1	+2	0
8	0	2	+4	0
9	0	3	+6	0
10	0	4	+8	0
11	0	5	+10	0

is dried, the honeycomb core layer and the upper and lower panels are bonded with No. 801 glue.

The tests in this paper were carried out under the conditions of relative humidity and room temperature of 80±2% and 20±1°C, respectively. The test was divided into two groups to test the effects of honeycomb dislocation and diatom mud sound-absorbing coating on the acoustic performance of the composite structure. Since only the honeycomb core layer was changed during the test, the same micro-perforated plate and aluminum plate were used. To compare the changes of the specimens, only the schematic and structure diagram of different honeycomb sandwich cores were given.

The first set of experiments changed the number of aligned honeycomb layers. The top view of the dislocation arrangement is shown in Figure 12. The six honeycombs were equally divided into six equal parts. The first set of tests respectively tested the influence of different dislocation stacked layers of honeycomb on the overall acoustic performance. The parameters are shown in Table 1 and the real one is shown in Figure 13. When discussing this variable, it should keep other parameters of the structure unchanged, only changing the stacking method, and changing it layer by layer with a gradient of 1 layer. The specimen numbers are 1–5.

The second group of tests changed the number of diatom mud coating layers. The number of diatom mud honeycomb layers gradually increased with a gradient of one layer between each group of tests. The part number is 6–11, and the relevant parameters are shown in Table 2. The schematic diagram of the honeycomb cells with different coating layers is shown in Figure 15. The brown part is the uncoated honeycomb, and the white part is the coated honeycomb. The actual picture is shown in the Figure 14 shown. Specimen 6 in the second group of tests and specimen 1 in the first group of tests are the same specimen. To facilitate comparison between tests, the aligned honeycombs of the two groups of tests are numbered, respectively.

(1) Influence of dislocation arrangement on the sound absorption performance of honeycomb core sandwich panels

According to the test results, the variation of the sound absorption coefficient with frequency of the first group of specimens (that is, changing the number of dislocation layers) is shown in Figure 16. The arrangement of the honeycomb core layer has little effect on the peak value of the sound absorption coefficient, which is basically the same as that of the aligned honeycomb. The peak value remains the same, and it has no great influence on the effective width of the sound absorption band. However, the internal arrangement of the core layer affects the resonant frequency of the composite structure. The resonant frequency moves to the low frequency with the increase of the number of dislocation layers, which improves the sound absorption performance of the middle and low frequency bands. Compared with the aligned structure, the fully dislocation structure moves to the low frequency direction about 300 Hz, which shows that compared with the aligned core layers, the dislocation structure has an improved absorption effect on mid- and low-frequency sound, but the absorption effect on mid- and high-frequency sound is not as good as that of the aligned honeycomb.

From the perspective of acoustic impedance as shown in Figure 17, in the frequency range of 300 Hz–1600 Hz, the dislocation structure affects the size of the acoustic impedance of

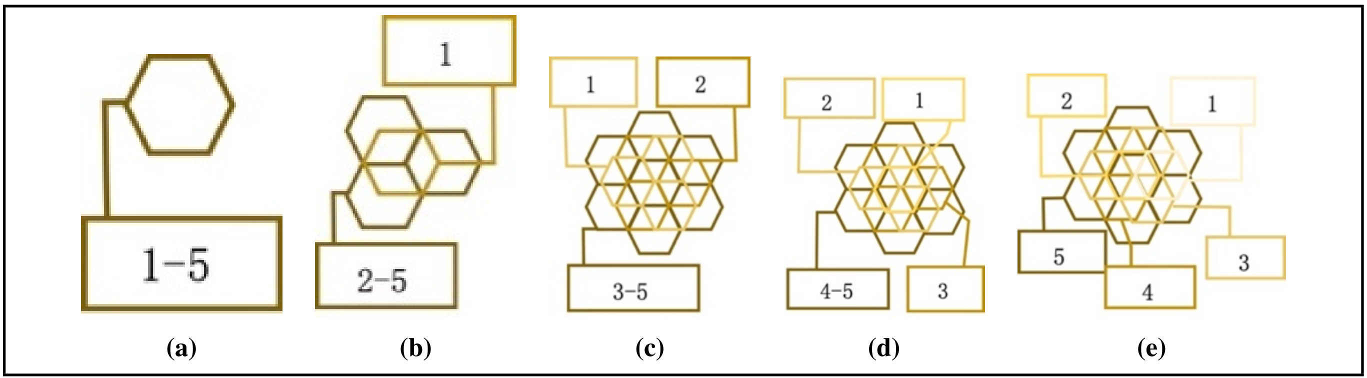

Figure 12. Top view of different dislocation layers: (a) zero layer; (b) two layers; (c) three layers; (d) four layers; (e) five layers.

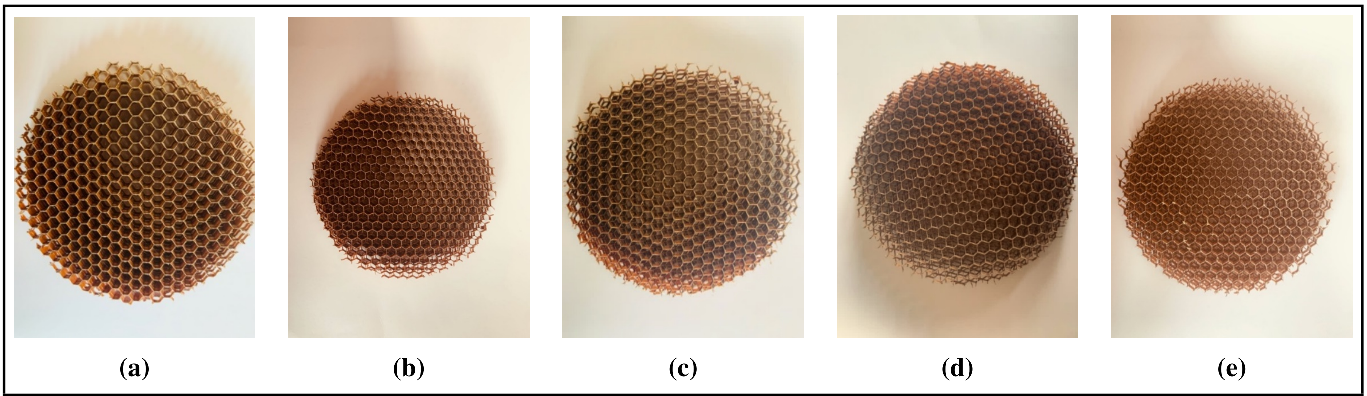

Figure 13. The first set of experiments (changing the number of dislocation layers of honeycomb): (a) No. 1, dislocation zero layer; (b) No. 2, dislocation two layers; (c) No. 3, dislocation three layers; (d) No. 4, dislocation Four layers; (e) No. 5, dislocation five layers.

the structure. The acoustic impedance of the structure first decreases and then increases with the increase of frequency. For the dislocation layer, the smaller the number, the smaller the fluctuation of the acoustic resistance. The acoustic impedance increases with the increase of frequency, and the dislocation structure increases the acoustic resistance of the composite board. Therefore, the structure with more dislocation layers reaches the intersection with the x-axis earlier, that is, the earlier it reaches the zero. The acoustic impedance zero corresponds to the frequency of the composite structure is the resonance frequency of the composite structure. The structure with more dislocation layers reaches the resonance frequency first. The staggered stacked honeycomb stacks the honeycomb skeleton in a staggered position. The honeycomb cells are divided to increase the number of honeycomb cells in space, which also increases the contact probability between the incident sound wave and the structure and increases the sound wave reflectivity. It is conducive to the full reflection of sound in the structure and to improve the acoustic performance of the structure.

Fitting the test results with the simulation results as shown in Figure 18, the peak sound absorption coefficient and the resonance frequency can be well fitted. However, because the test specimens are hand-made, there are some problems of misalignment angle or cementation, so that the sound absorption peak value of the simulation results is too large. The sound absorption coefficient is smaller than the test result after reaching the sound absorption peak value and the effective sound absorption bandwidth is narrower than the test results.

(2) Influence of diatom mud on the sound absorption performance of sandwich panels

The test results are shown in Figure 19. As the number of coating layers increases, the sound absorption coefficient first decreases and then increases. This is because the honeycomb wall thickness increases due to the existence of the coating in the process of making the specimen. The honeycomb and the micro-perforated plate are glued together. There may be a hole blocking situation, which reduces the perforation rate of the micro-perforated plate and affects the sound absorption performance. However, with the increase of the number of coating layers, the absorption effect of the sound wave increases, and the peak sound absorption coefficient increases accordingly. The overall fluctuation of the sound absorption coefficient is about 0.06. The diatom mud coating moves the resonance frequency to the low frequency. The full-coated structure moves 300 Hz to the low-frequency direction compared to the uncoated structure. When the sound wave propagates in the straight-tube honeycomb, due to the smooth surface of the honeycomb, there is only a small amount of energy loss near the wall surface which is not conducive to the dissipation of sound energy. However, the surface roughness of the honeycomb covered with diatom mud increases and the energy loss near the wall increases which is beneficial to the dissipation of sound wave energy.

The acoustic impedance and acoustic impedance of the honeycomb core sandwich panel covered with diatom mud coating are shown in Figure 20. From the perspective of acoustic impedance and acoustic impedance, the acoustic impedance of the overall structure first decreases and then increases with the increase of frequency. The coating makes the structural acous-

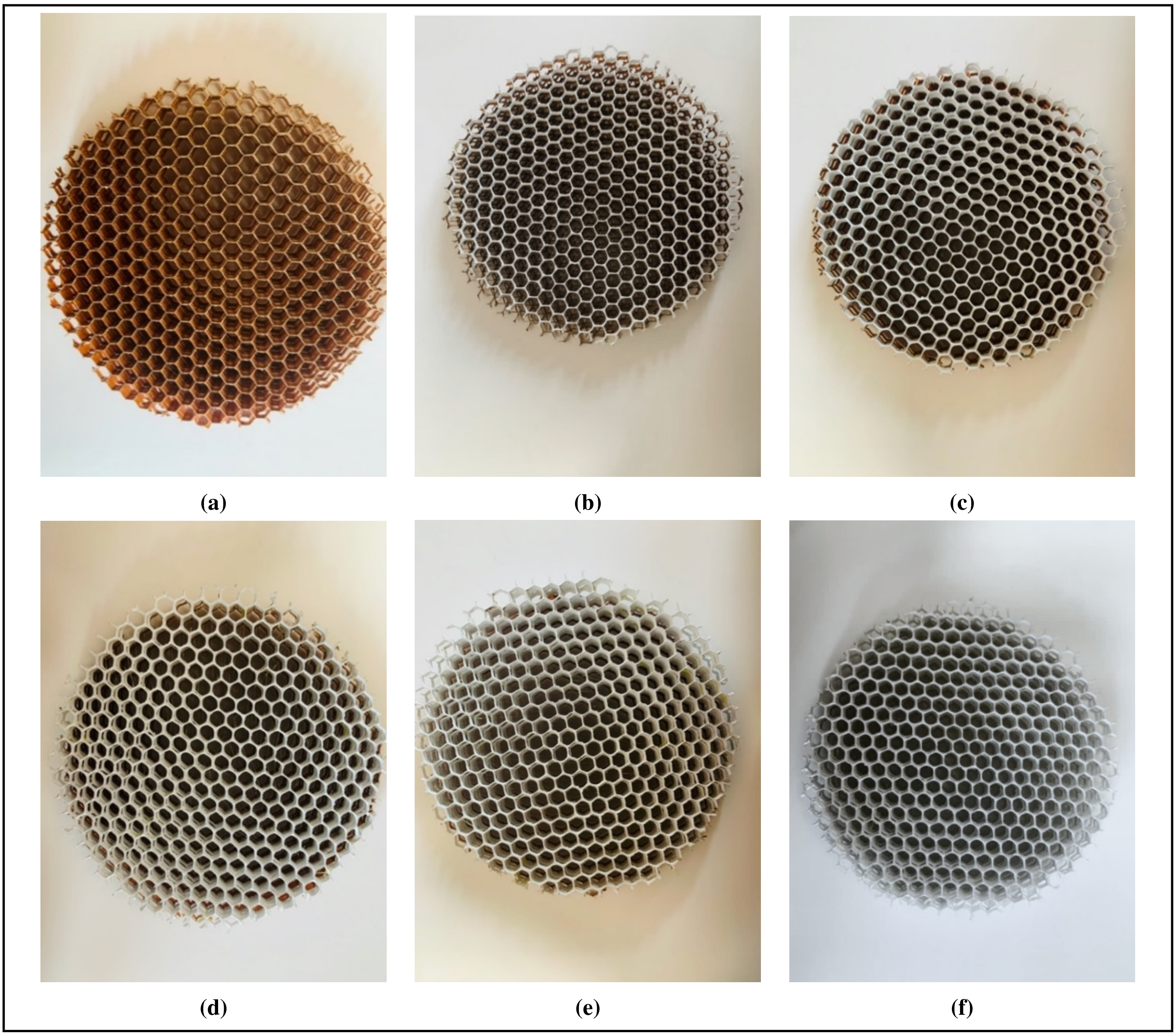

Figure 14. The second group of experiments (changing the number of aligned honeycomb diatom mud coatings): (a) No. 6, zero-layer coating; (b) No. 7, one-layer coating; (c) No. 8, two-layer coating; (d) No. 9, three-layer coating; (e) No. 10, four-layer coating; (f) No. 11, five-layer coating.

tic impedance increase. The acoustic resistance increases with the number of diatom mud honeycomb layers. The structure with more diatom mud honeycomb layers reaches the intersection with the x-axis first. The acoustic impedance and acoustic impedance of the composite structure are both affected by the diatom mud coating. The acoustic impedance and acoustic impedance of the test group covered with diatom mud are significantly higher than those of the uncoated structure. The sound absorption coefficient is the result of the combined effect of the acoustic impedance. The results of simulation and experiment show that the diatom mud coating has obvious improvement effects on the sound absorption coefficient in low frequency band.

As shown in Figure 21, by fitting the test results and the simulation results, the peak value of the sound absorption coefficient. The resonance frequency and the variation law of the test results fit well with the simulation results, which can basically confirm the reliability of the theoretical results. Due to the uneven coating in the test specimen, the increase of the honeycomb thickness due to the coating, which leads to microperforation and plugging. There are certain errors in the test results, so that the effective sound absorption frequency band of the simulation results is wider.

5. CONCLUSIONS

In this paper, the effects of the dislocation-arranged honeycomb core layer and the honeycomb core layer with built-in diatom mud coating on the sound absorption and noise reduction performance of sandwich panels are studied. When establishing the sound absorption model of the sandwich panel structure, the influence of the diatom mud coating on the sound absorption performance is considered. The theoretical model established by the acoustic-electrical analogy method was consistent with the test results of the impedance tube. The peak and resonant frequencies can be well fitted. The simulation and test results show that: the arrangement of the honeycomb core layer has little effect on the peak value of the sound absorp-

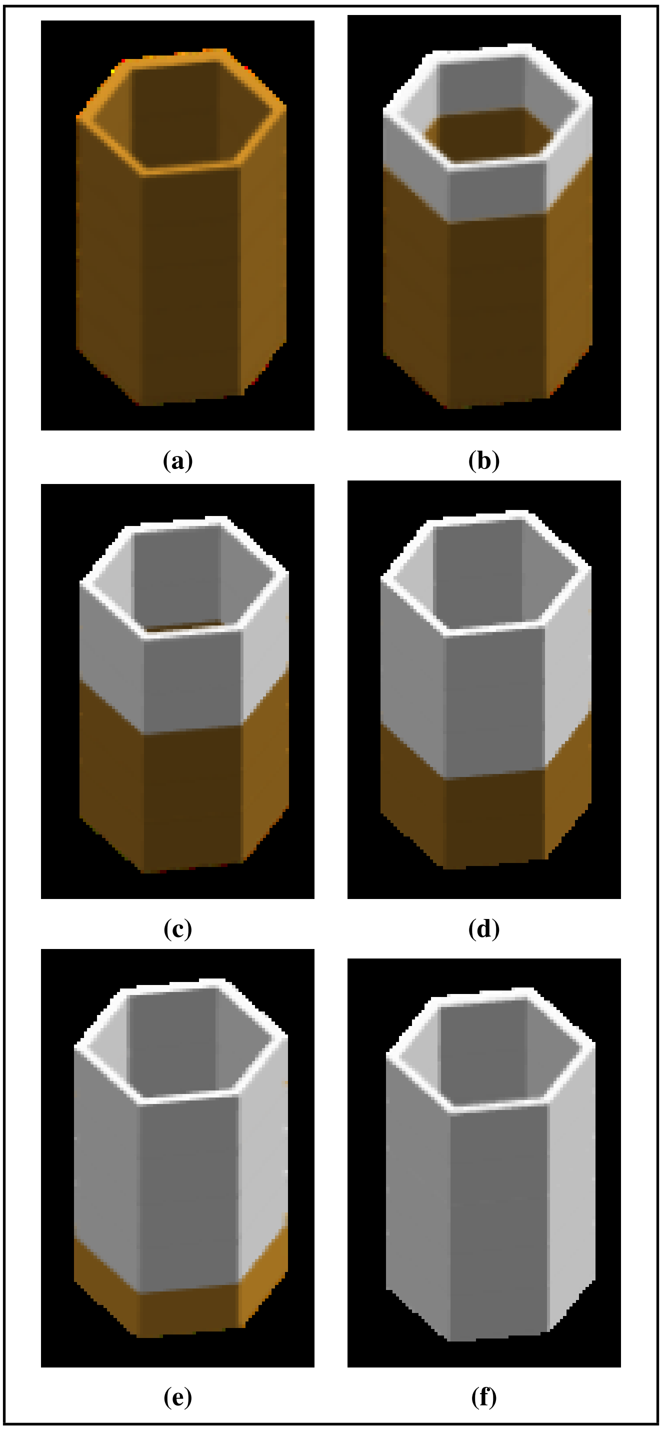

Figure 15. Schematic diagram of honeycomb cells with different coating layers: (a) zero layer; (b) one layer; (c) two layers; (d) three layers; (e) four layers; (f) five layers.

tion coefficient and the effective sound absorption bandwidth within 200 Hz∼1600 Hz, which is basically consistent with the peak value of the aligned honeycomb. The arrangement inside the core layer affects the peak value of the sound absorption coefficient and the effective sound absorption bandwidth. The resonance frequency of the composite structure moves to the low frequency direction with the increase of the number of dislocation layers and the full dislocation structure moves to the low frequency by 300 Hz compared with the aligned structure. In the test frequency band, as the number of dislocation layer increases, the acoustic impedance and acoustic impedance of the sandwich panel increase. The acoustic

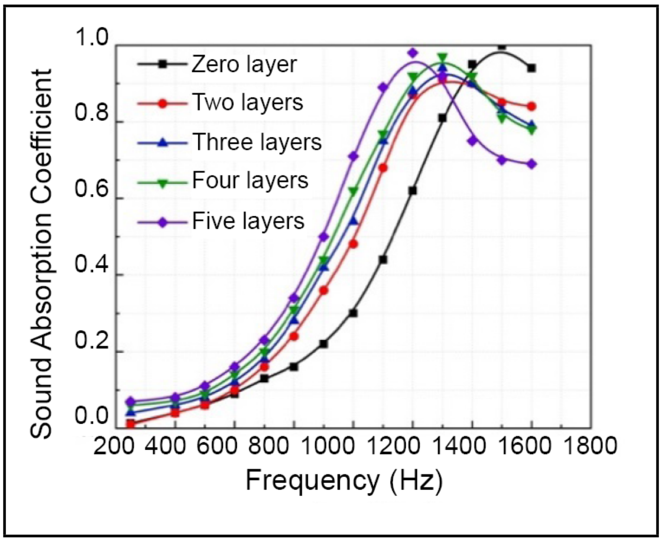

Figure 16. The effect of the number of dislocation layers on the sound absorption performance.

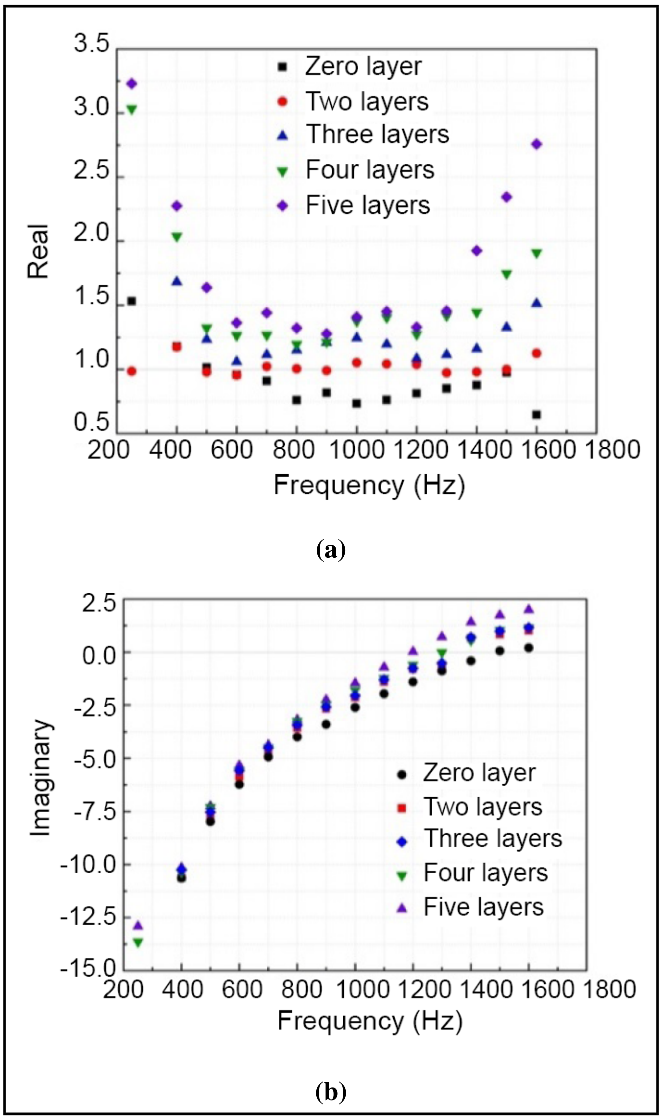

Figure 17. The effect of the number of dislocation layers on the acoustic impedance: (a) acoustic resistance; (b) acoustic impedance.

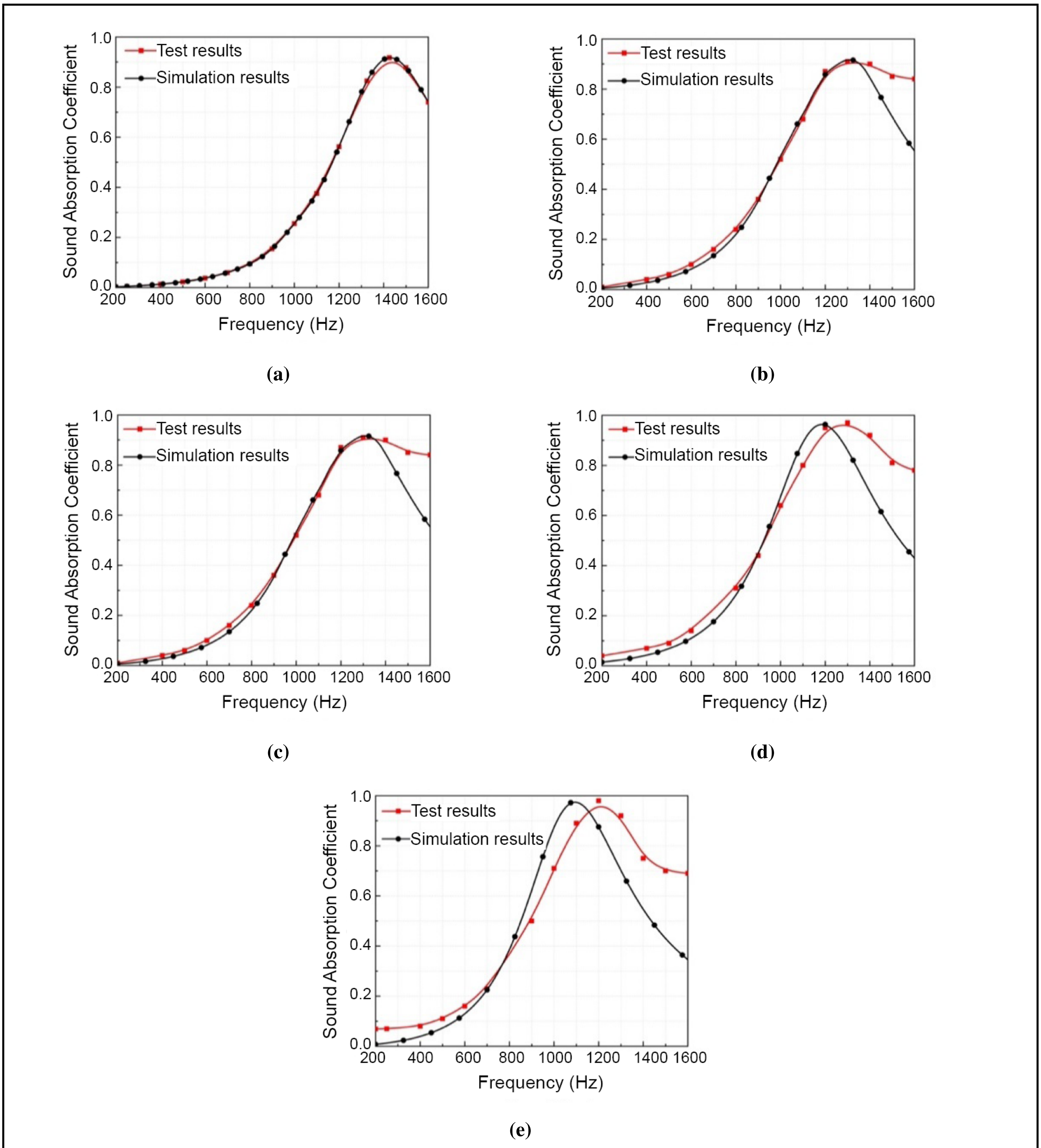

Figure 18. Fitting of test results and simulation results: (a) zero layer; (b) two layers; (c) three layers; (d) four layers; (e) five layers.

impedance of the structure decreases first and then increases with the increase of frequency. The less the number of dislocation layers, the fluctuation of acoustic impedance smaller. The coating has little effect on the sound absorption coefficient of the sandwich panel. But it can increase the width of the effective sound absorption band of the sandwich panel, increase the effective sound absorption range by about 100 Hz, and move the resonance frequency of the sandwich panel structure to low frequencies. The acoustic impedance of the overall structure decreases first and then increases with the increase of frequency. With the number of coating layers increasing, the acoustic impedance and acoustic impedance of the sandwich panel structure could increase.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

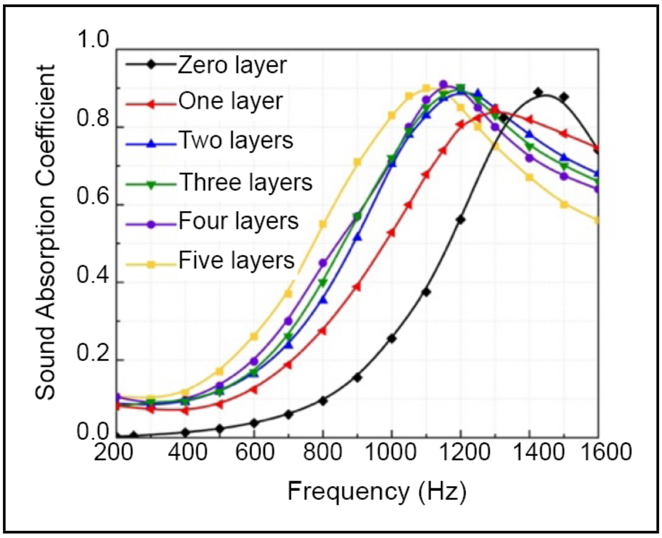

Figure 19. The effect of the number of coating layers on the sound absorption performance.

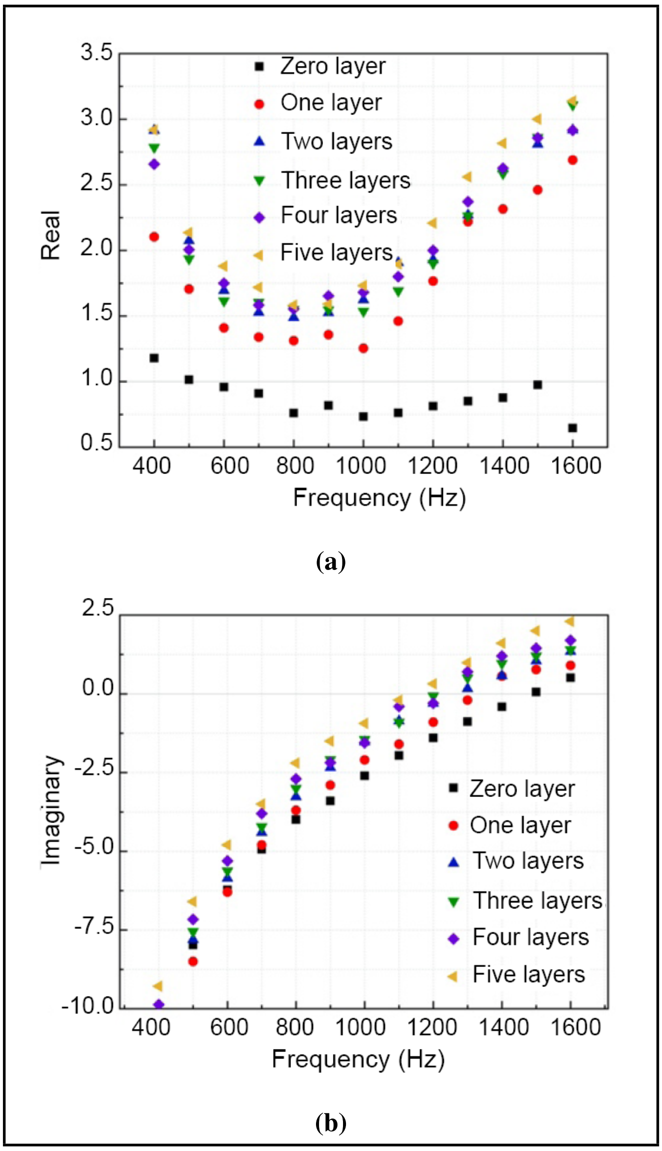

Figure 20. The effect of the number of coating layers on the acoustic impedance: (a) acoustic resistance; (b) acoustic impedance.

DATA AVAILABILITY STATEMENT

The data supporting the conclusion of the article are shown in the relevant figures and tables in the article. The data used to support the findings of this study are available from the corresponding author upon request.

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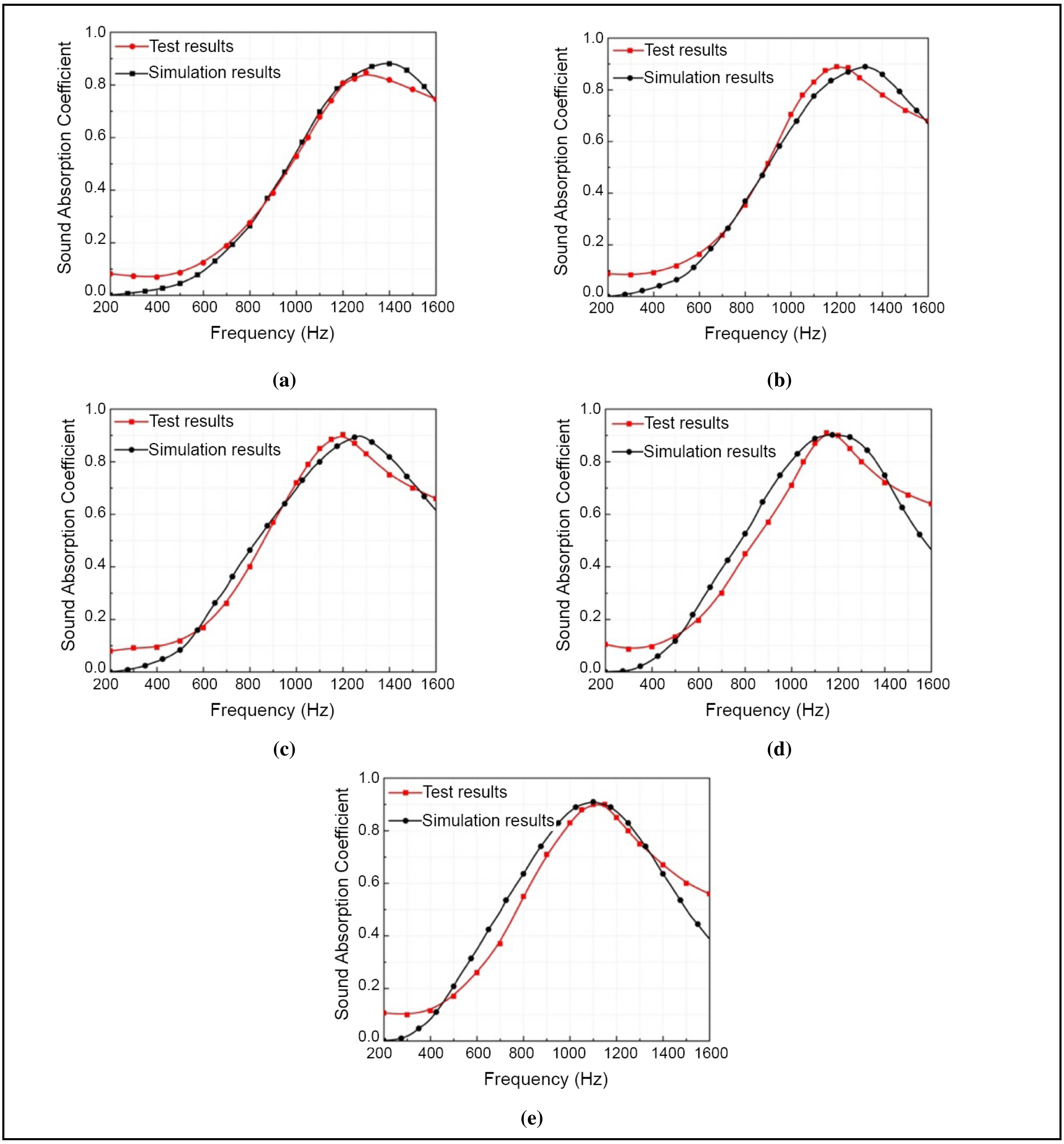

Figure 21. Fitting of test results and simulation results: (a) one layer; (b) two layers; (c) three layers; (d) four layers; (e) five layers.

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